



# Modeling and Performance Simulation of the Mass Storage Network Environment

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# Modeling and Performance Simulation of the Mass Storage Network Environment

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**Abstract:** This paper describes the application of modeling and simulation in evaluating and predicting the performance of the mass storage network environment. Network traffic is generated to mimic the realistic pattern of file transfer, electronic mail, and web browsing. The behavior and performance of the mass storage network and a typical client-server Local Area Network (LAN) are investigated by modeling and simulation. Performance characteristics in throughput and delay demonstrate the important role of modeling and simulation in network engineering and capacity planning.

## Introduction

Advances in computer network and communication technologies have increased the important role of modeling and simulation environment in system design, performance analysis, and development of communication protocols. The apparent benefit of modeling and simulation comes from the cost-effectiveness in evaluating the anticipated behavior of complicated systems. Since the system performance usually depends upon many inter-related parameters, a parametric simulation experiment can supplement and even replace the expensive and time-consuming hardware-based testing.

Many modeling and simulation tools are based on the discrete event simulation concept. In this approach, communication processes are decomposed into many states that can make a transition to different states depending upon the characteristics of the triggering events. Among several public domain tools, NS [1] provides a modeling and simulation environment for protocol development with substantial support for simulation of Transmission Control Protocol (TCP), routing, and multicast protocols. National Institute of Standards and Technology (NIST) Asynchronous Transfer Mode (ATM) simulator [2] is particularly suitable for performing research in ATM network. CSIM [3,4] is a flexible and general-purpose discrete-event simulation language for developing process-oriented simulation models. NetSim [5] is an event-driven simulator for packet networks with a simple X window interface to allow interactive use. BONEs and OPNET [6,7,8] are commercial tools that can be effectively utilized to predict the behavior of communication network and distributed systems.

The benefit of modeling and simulation also applies to the design and performance analysis of production network. As the trends in network management emphasize more proactive services for the end-users, a simulation capability is becoming an enabling technology in examining and analyzing the performance characteristics for network capacity planning. Modeling network configuration and simulating its behavior in response to the varying design and operating conditions is not only an economical way of evaluating the planned network but also provides network designers with a powerful tool to test a variety of potential network architectures and configuration scenarios.

In this work, the role of simulation and modeling in mass storage network environment is considered. In the first part, the performance characteristics of the mass storage network are examined. Based on the observed traffic trends, the mass storage network is modeled by two prominent networking technologies, Fiber Distributed Data Interface (FDDI) and ATM. Their performance is compared by simulation. The effect of internetworking devices and the link speeds upon the network delay characteristics is examined in the second part. OPNET (Optimized Network Engineering Tool) is used for the modeling of the network architecture, the performance measurement, and the presentation of the results. Among many performance-related statistics, the emphasis is given to the global parameters such as the throughput and the response time of the network.

## **Performance Prediction of the Mass Storage Network**

The core function of the server in the mass storage network is to permanently backup the data that are sent from the client workstations. These client stations also serve as the temporary file storage servers for the local subnet stations. Since the objective of the work is to evaluate the performance of the mass storage network, the temporary file storing function of the client workstations is ignored and it is assumed that the client workstations only generate traffic to the mass storage server. This appears to be a reasonable assumption since it is likely that the network bottleneck is at the link between the client stations and the server during the massive backup process.

In order to compare the overall performance of the different network technologies, FDDI ring and ATM switched topologies are modeled with the link speed of 100 Mb/s and 155 Mb/s respectively. Higher bandwidth (622 Mb/s) for the ATM uplink to the mass storage server was considered but was not included in the simulation for more fair comparison between two topologies.

The network model for the FDDI ring architecture is shown in Figure 1. Each of the client workstations is composed of a number of functional modules as in Figure 2 to mimic the layered architecture of the data flow. The client stations can simulate the majority of the popular applications such as E-mail, FTP, HTTP, Telnet, Video conferencing, X windows, database as well as user-specified custom applications. The server station basically has the same modular architecture except that the client module is replaced by the server module. Details of the module descriptions and the protocol parameters are beyond the scope of this work.

In order to measure the performance statistics, data traffic has to be injected into the network. Typical amount of the files for the mass storage network is reported at about 20 terabytes a month with the file sizes varying from a few thousand to millions of bytes. This monthly traffic corresponds to nearly 62 Mb/s and it is highly probable that it will increase further in the future. The traffic characteristics for the current simulation were established such that all nine client stations transfer files to the server at a constant traffic rate and a constant file size. Note that the traffic characteristics could also be individually established at a different rate and size for each client station.

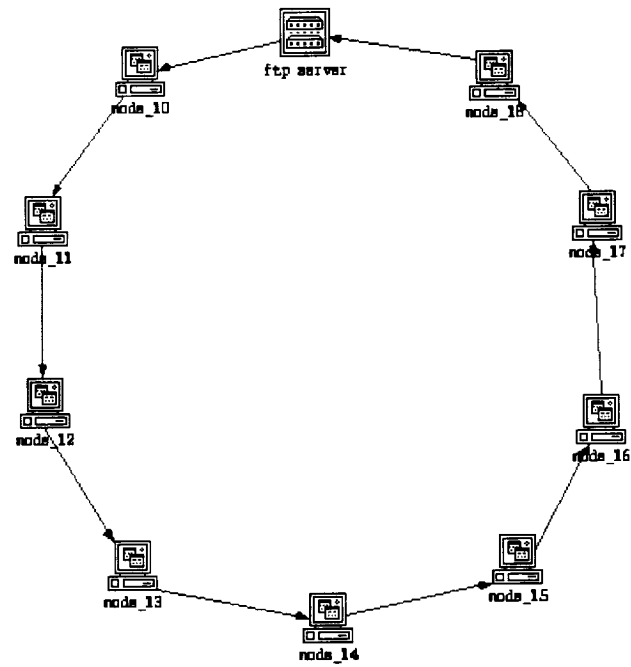


Figure 1. The FDDI network model.

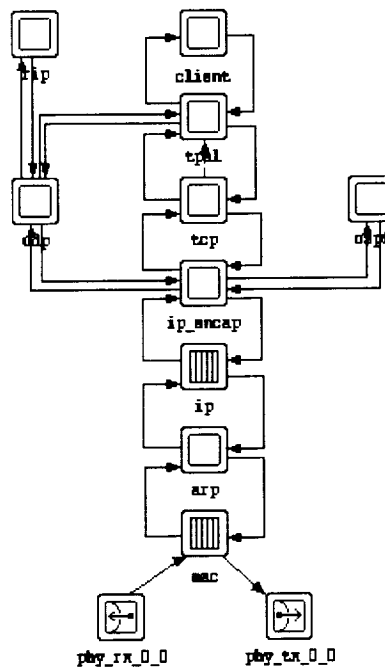


Figure 2. FDDI client node.

An ATM switched mass storage network can be a viable option to alleviate the potential troubles of the FDDI architecture due to a long delay and the suffering of the throughput. In Figure 3, the network model for the ATM switched mass storage architecture is shown along with the depiction of the client station's modular architecture in Figure 4.

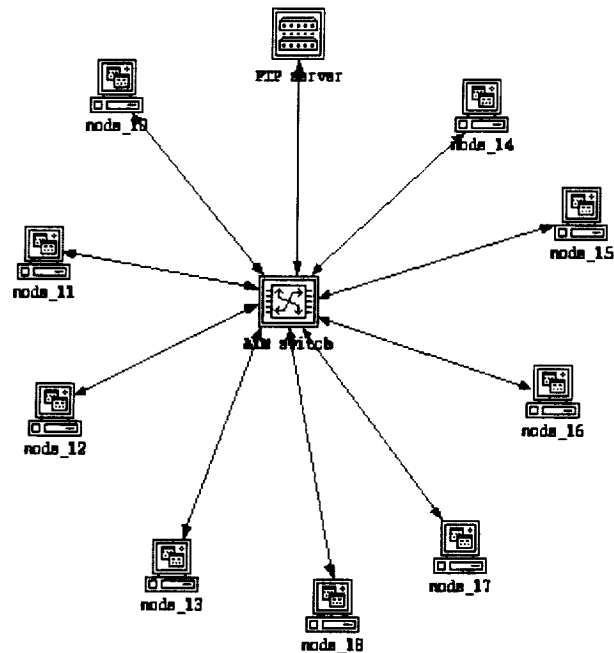


Figure 3. The ATM network model.

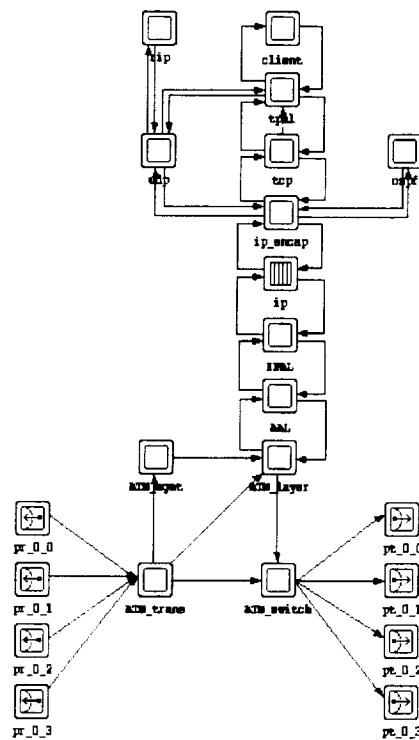


Figure 4. ATM client node.



Note again that the client workstation consists of modules in Figure 4 that mimic the data flow and the functionality of the layered architecture. The ATM switch consists of the modules similar to those of the client station below the AAL(ATM Adaptation Layer) module and is connected to the clients and the server at the link speed of 155 Mbits/sec.

In order to compare the performance of the FDDI model vs. the ATM model, an identical traffic was injected into each of the models. In this work, the file transfer is the only application that generates the traffic and all other applications were turned off. All files are destined to the server according to the respective access protocols and there is no file that is extracted from the server. Performance can be measured at each individual node of the model as well as in a global sense. In this work the focus was on the global behavior of the network and thus among numerous performance related parameters, the global throughput and the application response time were measured. The global application throughput is defined by the average bits per second forwarded to the application by all transport layers in the network and the application response time is measured from the time a client application sends a request to the server to the time it receives a response packet.

Figure 5 shows the simulated results for these two parameters. The abscissa here corresponds to the simulation time. The file transfer rate from each client station was set at 500 files/hr with the file size fixed at 50 Kbytes.

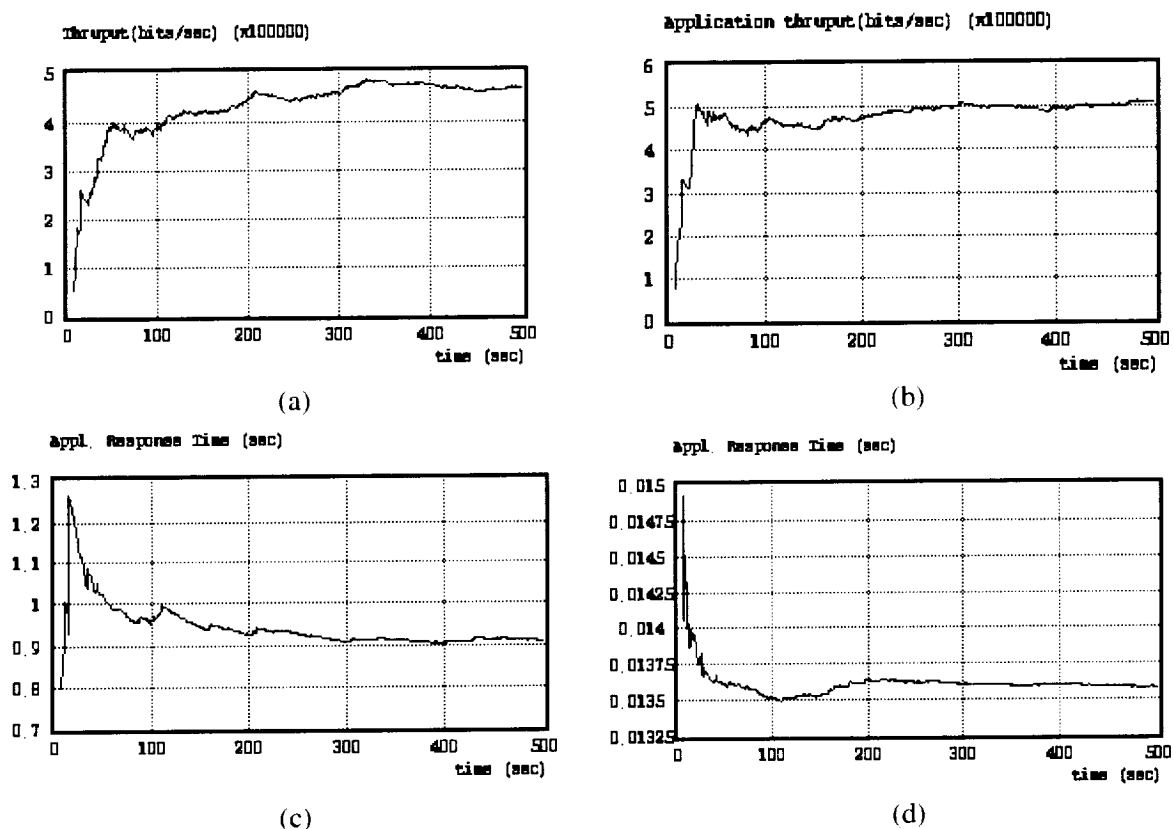


Figure 5. Performance statistics of FDDI and ATM models at the light traffic.  
Application throughput (a) ATM (b) FDDI.  
Mean application response time (c) ATM (d) FDDI.

In this figure, both FDDI and ATM models are shown to handle the traffic without any trouble, but the application response time for the ATM model is unexpectedly larger than that of the FDDI model. This discrepancy appears to be due to the fact that the application response time is the accumulation of all delays that span from the physical layer module to the application layer module as depicted in Figure 4. This means that the delays at the layer interfaces could significantly contribute to the total application response time. Since the conversion between ATM cells and IP packets (segmentation and reassembly) at IP-ATM interface can take much of the application response time in ATM model, it might be more desirable that the effect of the interface delays is isolated for a better comparison.

Figure 6 supports this speculation. Here, the FDDI end-to-end delay and the ATM end-to-end delay were measured for the same network models and the traffic. This statistics is defined by the delay that takes between the link layer modules of the sending and the receiving nodes and thus is the pure measurement of the link layer module performance. The ATM model is shown to outperform the FDDI model by more than an order of magnitude.

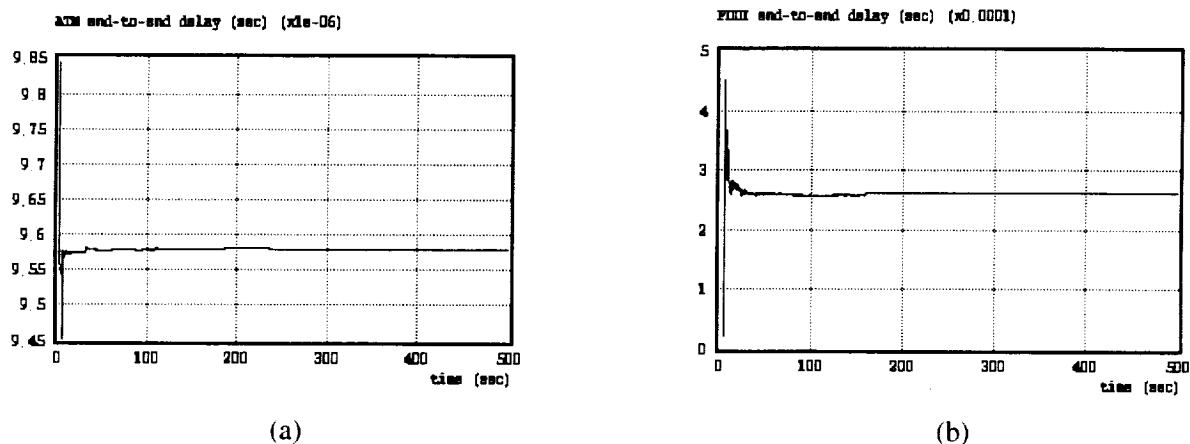


Figure 6. End to end delay at the link layer level (a) ATM (b) FDDI.

Further investigation showed that the SAR (Segmentation and Reassembly) rate of the ATM model plays a significant role for the application delay. This parameter is defined in the AAL module in Figure 4 and controls the rate of conversion between the IP packets and the ATM cells. Figure 7 depicts the application response time of the ATM model at an increased SAR rate and shows the smaller response time compared to that of the FDDI model in Figure 5.

Figure 8 shows the statistics for the file transfer rate of 10,000 files/hr at the file size of 50 Kbytes. Both FDDI and ATM models again handle the injected traffic smoothly with decent application response time.

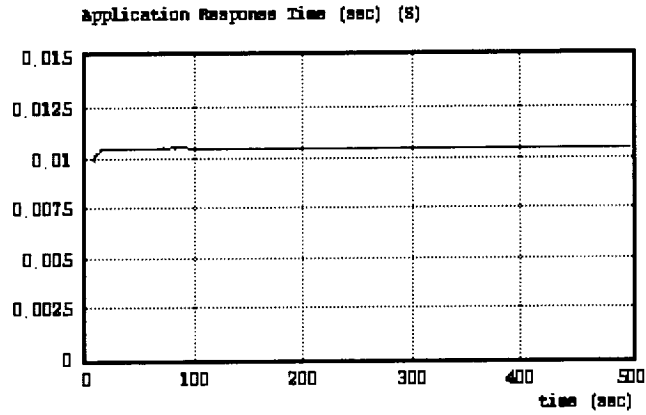
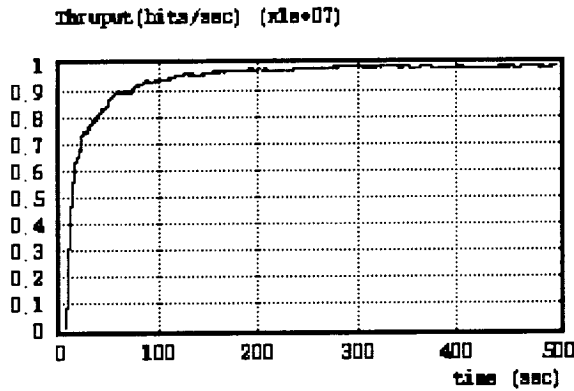
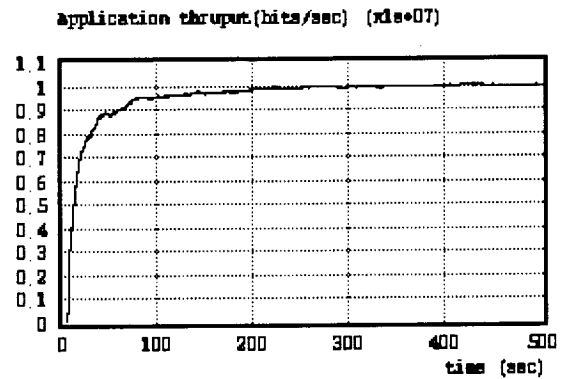


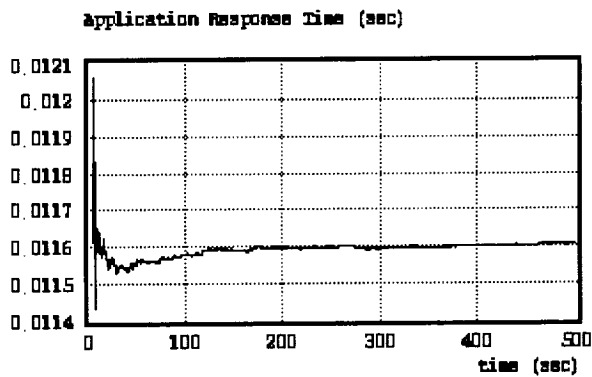
Figure 7. The mean application response time of the ATM model at an increased SAR rate.



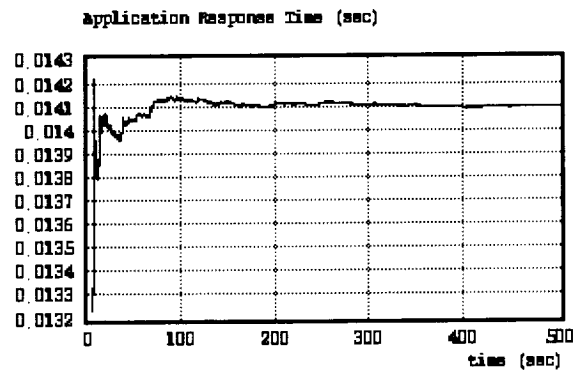
(a)



(b)



(c)



(d)

Figure 8. Performance statistics for a medium traffic.  
Application throughput (a) ATM (b) FDDI.  
Mean application response time (c) ATM (d) FDDI.

Another interesting experiment is to overload the FDDI network model to observe its behavior and compare with the ATM model. For this purpose a heavy traffic of 25,000 files/hr at the fixed file size of 200 Kbytes was applied to each model. The change in the file size from the previous simulations was made to decrease the simulation run time while keeping the total quantity of the traffic at 100 Mbits/sec. Also due to the restriction in the simulation run time, the ATM model simulation was interrupted after 300 seconds. It appears that this interruption does not cause any significant loss of useful performance statistics. Figure 9 shows the simulation results for this heavy traffic scenario. While the ATM model appears to achieve the full throughput of 100 Mbits/sec, the application throughput of the FDDI model levels off at 90 Mbits/sec. More critically, the application response time of the FDDI model monotonically increases to an unacceptable value due to the overloading of the network. Same statistics for the ATM model still graciously holds at a decent value.

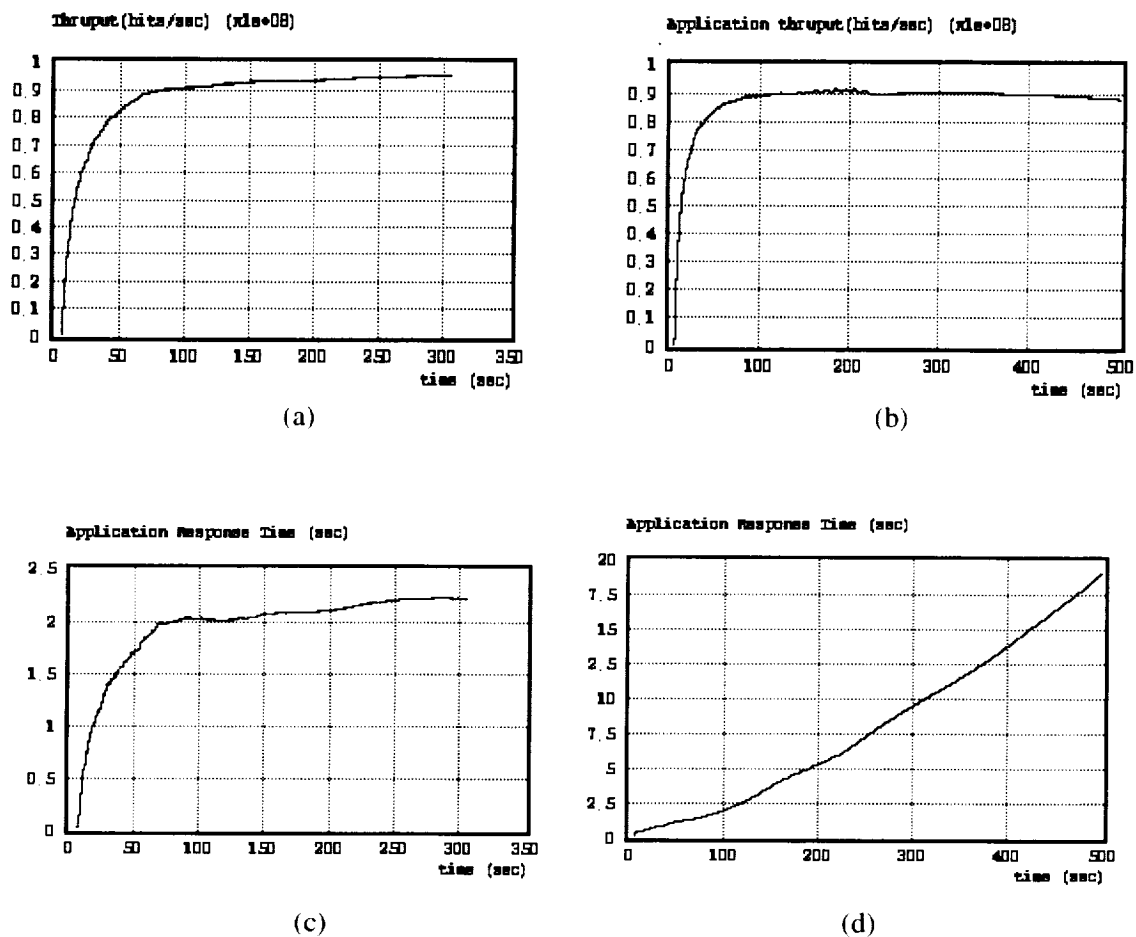


Figure 9. Performance statistics for the heavy traffic.  
 Application throughput (a) ATM (b) FDDI.  
 Mean application response time (c) ATM (d) FDDI.

## Modeling and Simulation of a Client-Server LAN

The critical factors determining the performance characteristics in the previous section are the speed of the communication link (FDDI:100 Mbps, ATM:155 Mbps) and shared (FDDI) vs. switched (ATM) network. In this section, a simple client-server model is considered to investigate the effect of these factors on the performance of a typical Ethernet LAN. As depicted in Figure 10, the network has a star topology and consists of one server (node\_31) and thirty client workstations connected through either a hub or a switch (node\_30). Client nodes request the server applications such as electronic mail, file transfer, and web browsing. For modeling purpose, the server is assumed to have been configured to handle all the requested applications. Four different network configurations are investigated; a shared Ethernet (10BaseT to the hub, 10BaseT uplink to the server), a switched Ethernet (10BaseT to the switch, 10BaseT uplink to the server), a switched Ethernet with a 100BaseT uplink to the server, and a switched Fast Ethernet with a Gigabit uplink to the server. The Ethernet delay is measured for each configuration and compared. The Ethernet delay is defined as the end to end delay of all packets received by all the stations and represents a global performance of the network.

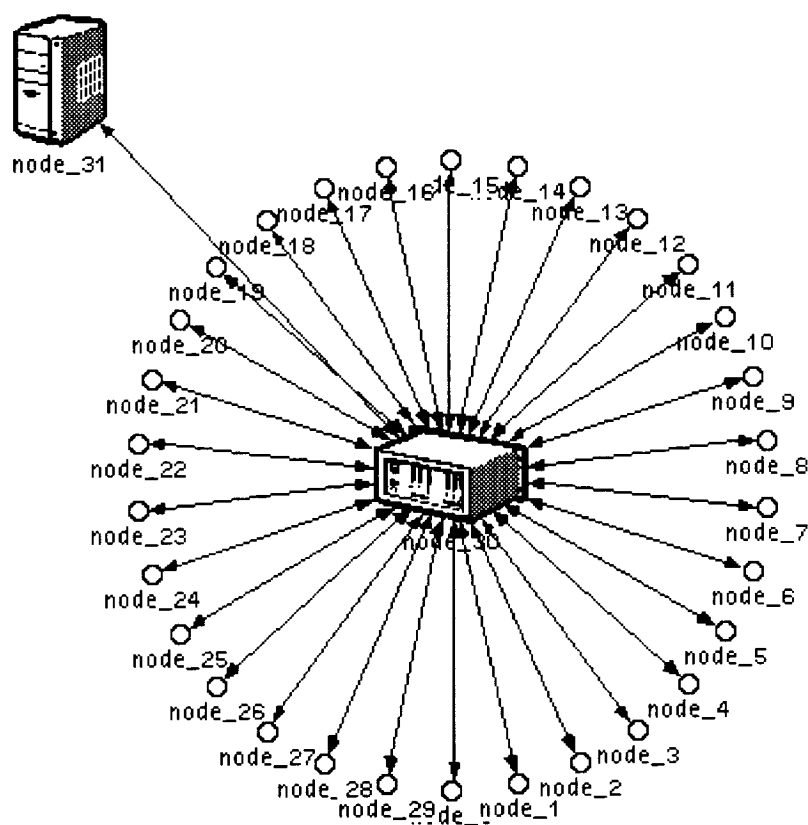


Figure 10. The Client-Server LAN Model.

The characteristics of the application traffic are modeled to mimic the realistic loading on the network as shown in Table 1. Although each of these traffic characteristics can be distinctively applied to each client node, an identical traffic pattern was applied to each of the thirty client nodes in this work.

Table 1. Application Traffic Parameters.

Application	Send Rate(Messages/Hour)	Receive Rate(Messages/Hour)	Average E-Mail Size(Bytes)
E-Mail	10	10	2,000

Application	Command Mix(Get/Total)	File Transfer Rate(Files/Hour)	Average File Size(Bytes)
File Transfer	50%	10	50,000

Application	Page Rate(Pages/Hour)	Page Size(Objects/Page)	Average Object Size(Bytes/Object)
Web Browsing	60	10	12,000

A simulation was run for 10 minutes and the Ethernet delay was measured for each network configurations. In order to minimize initial transient behavior during simulation, each of the client nodes is configured to begin application request after the simulation is run for 100 seconds. Figure 11 shows the time-averaged Ethernet delay for each network configurations. In symbol notation, each symbol is followed by the internetworking device, link speed from the client node, and the uplink speed. The simulation result demonstrates the performance advantage of the switched Ethernet over the shared Ethernet. The effect of link speed is also apparent. Note that the 100BaseT switched Ethernet with Gigabit uplink shows almost no delay in the current scale of the plot.

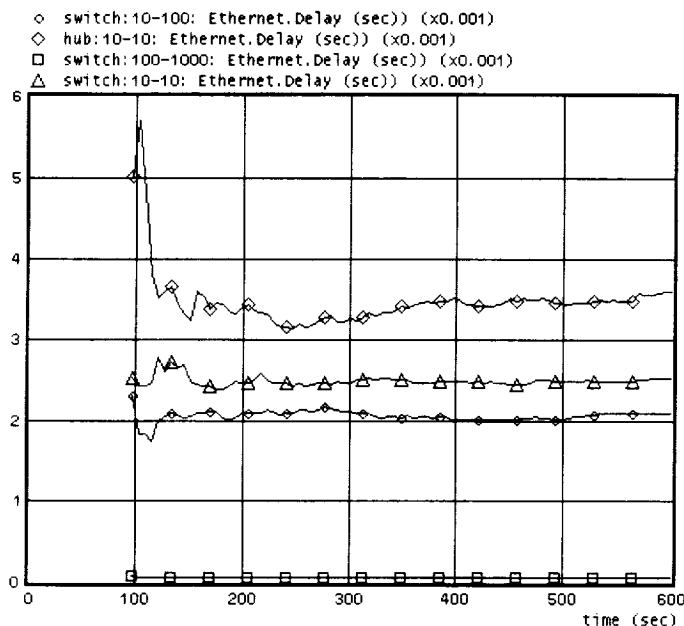


Figure 11. Comparison of Ethernet Delay.

## Summary

In this work the performance of several different network technologies and topologies is evaluated using a modeling and simulation. The simulation results appear to follow the realistic behavior of the network under the applied traffic. This work demonstrates that modeling and simulation can be an effective tool for designing and planning a future network under different scenarios. It provides an enabling technology to proactively serve the networking demand of mission and business-critical applications. It also augments the network equipment testing by minimizing the cost and time of hardware testing.

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